

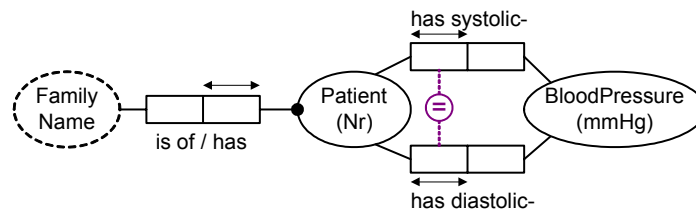
## Verbalizing Business Rules: Part 8

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Business rules should be validated by business domain experts, and hence specified using concepts and languages easily understood by business people. This is the eighth in a series of articles on expressing business rules formally in a high-level, textual language. The first article [4] discussed criteria for a business rules language, and verbalization of simple uniqueness and mandatory constraints on binary associations. Article two [5] examined hyphen-binding, and verbalization of internal uniqueness constraints that span a whole association, or that apply to  $n$ -ary associations. Article three [6] covered verbalization of basic external uniqueness constraints. Article four [7] considered relational-style verbalization of external uniqueness constraints involving nesting or long join paths, as well as attribute-style verbalization of uniqueness constraints and simple mandatory constraints. Article five [8] discussed verbalization of mandatory constraints on roles of  $n$ -ary associations, and disjunctive mandatory constraints (also known as inclusive-or constraints) over sets of roles. Article six [9] considered verbalization of value constraints. Article seven [10] examined verbalization of subset constraints. This eighth article discusses verbalization of equality constraints.

### Verbalization of equality constraints between single roles

Figure 1 shows a fragment from an ORM schema about hospital patients discussed in [11]. The circled “=” connecting the roles played by Patient indicates that for each state of the business domain, the population of these two roles must be equal. In other words, if we know a patient’s systolic BP (blood pressure), we also know his/her diastolic BP, and vice versa. This illustrates a simple *equality constraint* between two fact type roles. An equality constraint may be applied only if the roles are compatible (i.e. based on identical or overlapping types). At the external level, BP is usually displayed as a single figure, for example 120/80, read as “120 over 80”, where the first number measures the systolic blood pressure (maximum pressure exerted when the heart contracts) in millimeters of mercury, and the second number indicates the diastolic blood pressure (pressure in the arteries when the heart is at rest). In this schema, the two facts underlying the overall BP reading are displayed separately.



**Figure 1** An equality constraint between single roles.

This equality constraint may be formally verbalized in any of the following ways:

**Each Patient who has a systolic BloodPressure also has a diastolic BloodPressure and conversely.**

**For each Patient:**

**that Patient has a systolic BloodPressure if and only if that Patient has a diastolic BloodPressure.**

**For each Patient<sub>1</sub>:**

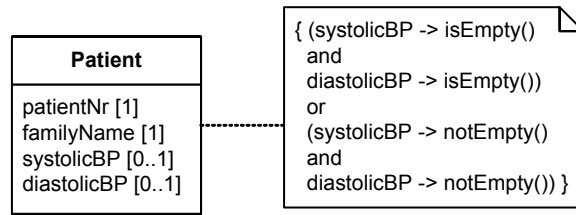
**Patient<sub>1</sub> has a systolic BloodPressure if and only if Patient<sub>1</sub> has a diastolic BloodPressure.**

**If a Patient has a systolic BloodPressure then that Patient has a diastolic BloodPressure and conversely.**

**If a Patient has a systolic BloodPressure then that Patient has a diastolic BloodPressure and if a Patient has a diastolic BloodPressure then that Patient has a systolic BloodPressure.**

The last two readings reflect the fact that an equality constraint between two arguments is equivalent to a conjunction of two subset constraints, one in either direction. As usual, the pronoun “who” may be replaced by “that” or “which”, the quantifier “a” may be replaced by “some”, “at least one”, or “an”, “for each” may be replaced by “given any”, and “if and only if” may be abbreviated to “iff”. As explained in an earlier article [5], the use of hyphens in the predicates binds the adjectives “systolic” and “diastolic” to the object type name, so the quantifier “a” precedes them in the verbalization.

Figure 2 shows a UML class diagram for our patient example, assuming that the blood pressure facts are modeled in terms of attributes rather than associations. As there is no graphic way of depicting the equality constraint in UML, it is expressed in OCL within an attached note. Because the note is attached to the Patient class, this is understood to provide the context for the OCL constraint. Clearly, each of the verbalization patterns shown above provides a higher level declaration of the constraint that is more likely to be understood by a non-technical domain expert.



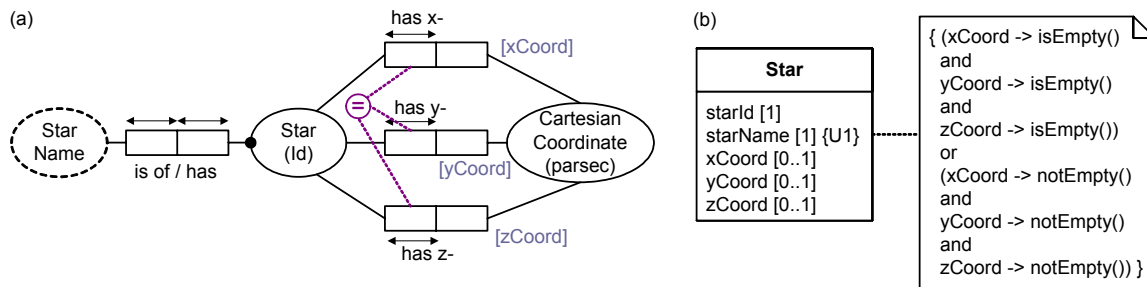
**Figure 2** The ORM schema from Figure 1 expressed as a UML class diagram.

In addition to the relational-style verbalization already discussed, an attribute-style verbalization may be provided, as follows. Although less natural than the relational-style verbalization, it is likely to be more understandable to non-technical people than the OCL formulation.

**For each Patient:**  
 systolicBP **exists if and only if** diastolicBP **exists**.

Note that this verbalization may also be applied directly to the ORM schema, so long as we supply the attribute names used in the UML diagram as corresponding role names on the ORM schema.

Though rare in practice, an *n*-ary version of an equality constraint may be applied to a set of three or more compatible roles (or role-sequences). This is equivalent to multiple binary equality constraints between all the pairs of roles (or role-sequences). A simple example is shown in Figure 3, in both ORM and UML notations. The “{U1}” annotation is a non-standard extension to UML to express the uniqueness constraint that each star name refers to at most one star [6].



**Figure 3** An *n*-ary equality constraint in (a) ORM, and (b) UML.

Such *n*-ary constraints may be verbalized either as conjunctions of *n*-1 binary constraints, or directly as follows in relational-style or attribute-style (the latter verbalization applies also to the ORM schema, using the role names supplied there). If desired, a synonym for “not exists” such as “is absent” may be introduced. Note that there is no simple extension based on “iff”; for example, *p* iff (*q* and *r*) is true in some cases other than the cases where *p*, *q*, and *r* are either all true or all false.

For each Star all or none of the following are true:

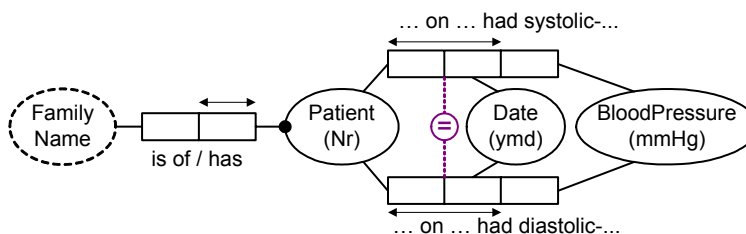
- that Star has an x-CartesianCoordinate;
- that Star has a y-CartesianCoordinate;
- that Star has a z-CartesianCoordinate.

For each Star:

- (xCoord exists and yCoord exists and zCoord exists) or
- (xCoord not exists and yCoord not exists and zCoord not exists).

### Verbalization of equality constraints between role sequences

Equality constraints may also be specified between compatible *role sequences* (of two or more roles). Consider a hospital domain where patients may have their blood pressure measured at most once a day, and where a history is kept of the results. Figure 4 shows one way to model this in ORM. Here the equality constraint is between the Patient-Date role-pairs projected from the two ternary associations. The constraint indicates that for any given patient and date, we know either both the systolic and diastolic BP readings, or neither reading.



**Figure 4** An equality constraint between role-pairs.

This pair-equality constraint may be verbalized in relational style as follows.

**Each Patient who on a Date had a systolic BloodPressure also on that Date had a diastolic BloodPressure and conversely.**

**For each Patient and Date:**

- that Patient on that Date had a systolic BloodPressure
- if and only if**
- that Patient on that Date had a diastolic BloodPressure.

**For each Patient<sub>1</sub> and Date<sub>1</sub>:**

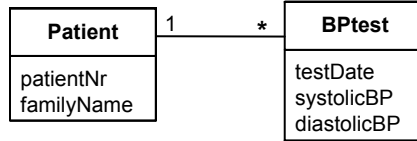
- Patient<sub>1</sub> on Date<sub>1</sub> had a systolic BloodPressure
- if and only if**
- Patient<sub>1</sub> on Date<sub>1</sub> had a diastolic BloodPressure.

**If a Patient on a Date had a systolic BloodPressure then that Patient on that Date had a diastolic BloodPressure and conversely.**

**If a Patient on a Date had a systolic BloodPressure then that Patient on that Date had a diastolic BloodPressure and if a Patient on a Date had a diastolic BloodPressure then that Patient on that Date had a systolic BloodPressure.**

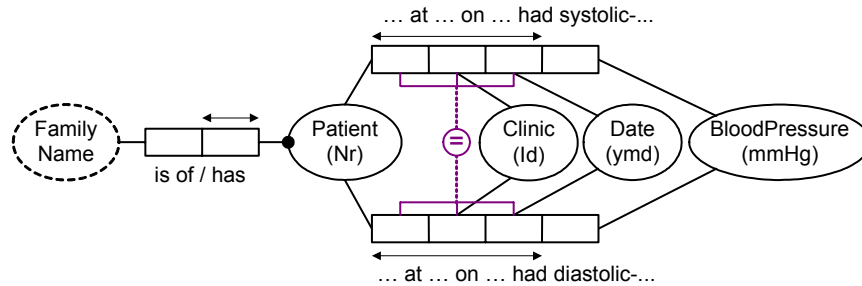
As discussed in earlier articles, if the same object type plays more than one role in an association, either role names, or numeric subscripts appended to the object type name, may be used to distinguish the role players.

In UML it would be unusual to model this example using ternary associations. Instead one would normally introduce a BPtest class, as shown in Figure 5 (an identifier for BPtest is assumed). This removes the need to verbalize a role-sequence equality constraint in this case. Note that this modeling alternative would normally be preferred in ORM as well, where an explicit identifier such as TestNr would be also included to identify blood pressure tests. For a discussion of optimization heuristics for ORM schema transformation, see chapter 12 of [1].



**Figure 5** Remodeling in UML of the Figure 4 domain avoids the need for an equality constraint.

These verbalization patterns may be extended in obvious ways to cater for other cases, where the role-sequences may contain more than two roles, or are projected from a role path spanning multiple associations. As a simple example of the former, consider the equality constraint in Figure 6. Here each role sequence contains three roles projected from one of the ternaries. In this domain, patients may have their blood pressure measured at any given clinic at most once a day, but may attend multiple clinics on the same day. A history is kept of the results.

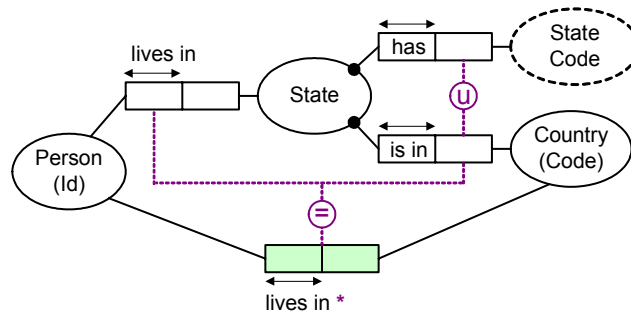


**Figure 6** An equality constraint between two role-sequences, each of which contains 3 roles.

This equality constraint may be verbalized by simply generalizing the previous patterns. For example:

**For each Patient, Clinic and Date:**  
**that** Patient **at that** Clinic **on that** Date **had a** systolic BloodPressure  
**if and only if**  
**that** Patient **at that** Clinic **on that** Date **had a** diastolic BloodPressure.

As a simple example of a subset constraint involving a *projection from a role path*, consider the ORM schema shown in Figure 7. The equality constraint declares that a person lives in a country if and only if that person lives in a state that is in that country. Here one role pair comprises the predicate within the fact type Person lives in Country. The other role pair is obtained by projecting on the first and last roles of the join path Person lives in a State **that** is in Country. This path involves a *conceptual join* between the roles on that path that are played by State. For further discussion of such join-constraints, see [2].



**Figure 7** An equality constraint involving a role path projection.

The asterisk on the Person lives in Country association indicates that this fact type is *derived*. In this case, the *derivation rule* is captured by the equality constraint, and may be verbalized thus:

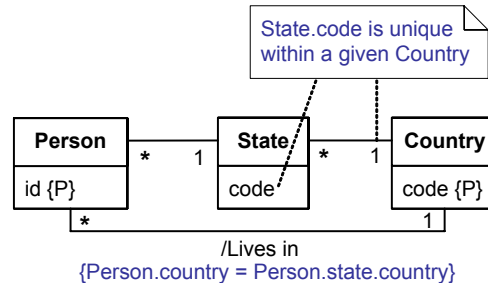
Person lives in Country iff  
 Person lives in a State that is in that Country.

If this rule is added as a textual derivation rule to the ORM diagram, the graphical equality constraint would normally be omitted. Note that the left-hand expression in the rule denotes a simple fact type, while the right-hand side of this verbalization applies the existential quantifier (“a”) to the join object type (State) on the role path. The equality constraint is suitable for deriving the left-hand fact type, but cannot be used to derive the state in which a person lives. The high level verbalization of the rule may be formally captured by the following logical expression:

$$\forall x:\text{Person} \forall y:\text{Country} [x \text{ lives in } y \equiv \exists z:\text{State} (x \text{ lives in } z \ \& \ z \text{ is in } y)]$$

If one argument of an equality constraint comprises all the roles in a fact type  $F$ , and the other argument is a role projection from a path containing more roles, then the equality constraint provides a *full derivation rule* (iff rule) for the fact type  $F$ . Similarly, a subset constraint from a role projection to a fact type provides a *partial derivation rule* (if rule) for that fact type. For example, if we can know that some people live in some country without knowing the state they live in (our knowledge is incomplete), then the equality constraint is replaced by a subset constraint, and the fact type Person lives in Country is only partially derivable from the join path.

Full (but not partial) derivation rules for a fact type may be captured in UML by annotating the derived association with a slash “/”, and adding the derivation rule in text. In Figure 8 this rule is specified in OCL [13]. This attribute version of the rule may also be used in ORM if desired. As UML lacks any graphical notation for specifying value-based identification schemes, I’ve indicated the simple identification schemes using “{P}” and the composite identification scheme with a note. I’ll say more about derivation rules in a later article.



**Figure 8** Specifying a derivation rule in UML.

That completes our coverage of equality constraints and their verbalization. The next article considers exclusion constraints.

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